Research Article

Authorship Trends in the *Journal of Orthopaedic Research*: A Bibliometric Analysis†

Running Title: JOR Authorship Trends

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Abstract

Publications are an important tool to measure one's success and achievement in academia. They can help propel a career forward and move one into a position of leadership. The overall purpose of this study was to investigate changes in bibliometric variables, authorship, and collaboration trends in the *Journal of Orthopaedic Research* (*JOR*®), since its inception in 1983. A bibliometric analysis was completed for all manuscripts meeting the inclusion criteria (638), which were published throughout the inaugural year plus one representative year of each decade. Several parameters were investigated including numbers of manuscripts, authors, collaborating institutions/countries, references, pages, and citations; region of origin and gender of authors over time and by region were main focuses. Significant increases over time were observed in all bibliometric variables analyzed except in the number of pages and citations. There was an approximate 27 percentage point increase for both female first and corresponding authors from 1983 to 2015. While this is most likely due to the increase in the number of women that have entered the field over time, similar increases in the percentage of women holding positions on the *JOR* editorial board or in leadership positions within in the field may have also contributed to improvements in gender parity. Understanding changes in publishing characteristics over time, by region, and by gender are critical, especially with the rising demands of publishing in academia. *JOR* has seen increase in most variables analyzed, including improvements in authorship by women in the field of orthopaedic research.

Key Words: Bibliometric, Authorship Trends, Gender, Time, Country

Introduction

The Orthopaedic Research Society (ORS) is one of the leading groups that supports and encourages research in orthopaedics and musculoskeletal disease. As the *Journal of Orthopaedic Research* (*JOR*®) is the official journal of the ORS, we believed it would be appropriate to review authorship changes over the past 30 years in *JOR*® for many bibliometric variables, such as gender, number of authors, corresponding author position, collaboration between institutions and countries, manuscript length, number of references, and citations, and explore these variables between different regions of the world and over time. With the rising demands of publishing in academic medicine, understanding changes in publishing trends may provide insight as to successes over time and challenges that persist. As orthopaedics has traditionally been a male dominated field, one particular focus of this manuscript was on authorship gender.

According to the Global Gender Gap Report 2016, gender gaps have markedly decreased over the past 10-15 years.[1] Women have also made substantial progress in medicine, with nearly equal numbers of women and men entering medical school in the United States.[1] However, progress remains slow as women are still underrepresented at the highest levels of leadership, with only 15% of academic department chairs and 16% of academic deans in 2014 being women.[2] Since 1983, ORS has had 6 female presidents (18%) compared to 27 male presidents (82%). Currently, 23% of ORS active members are women, and 40% of associate or in-training members are women (MAK personal communication, August 16, 2017 with ORS Membership and Affiliate Relations Specialist). With this in mind, we assessed the gender of the first and corresponding author, author gender over time, author gender across regions, and author gender across regions over time.

In addition to exploring gender-based authorship trends, we also examined how orthopaedic research is or is not growing in different regions of the world. To accomplish this, we assessed publications by region and publications by region over time. Further, we explored how collaborations have or have not grown within the orthopaedic research community. In general, collaboration in academic medicine has grown over the past 50 years. There has been an increased network of investigators from multiple institutions and across several disciplines in countries around the world that are now collaborating together on research. This is evidenced by the increase in multi-authored papers and an increase in the mean number of co-authors on papers recently published.[3] Additionally, there has been an increase in collaboration between authors of different countries over the past 10 years, which further contributes to the globalization of academic medicine.[4] We wished to determine if these trends held true for *JOR*. Here we used the number of institutions from which authors were affiliated, and the number of countries from which authors resided, as a proxy for the degree of collaboration. Finally, with increased collaboration/team science approaches along with the increasing importance of publications during all academic career stages, we expected to observe increases in the number of co-authors on each manuscript over time in *JOR*. Together, these represent several of the key authorship variables addressed in this manuscript.

Methods

Overview

This bibliometric analysis was performed using *JOR®'s* published manuscripts from the 1983 through 2015. We analyzed the first year of publication (1983) and one year from the middle of each decade (1985, 1995, 2005, and 2015). Many demographic variables were

analyzed including gender/number of authors, gender/position of corresponding author, geographic region of manuscript origin, number of pages and references in the manuscript, and the number of times it had been cited. The number of times the manuscript was cited was divided by the number of years since the manuscript was published to give a normalized citation value.

Data Collection Procedure

Data were collected in a manner similar to that described by other investigators.[5-13] In brief, data were collected at 10-year intervals working backwards from 2015, in addition to the 1983 inaugural year of *JOR*®. The year 2015 was designated as the starting year since it was the most recent year with complete PubMed (https://www.ncbi.nlm.nih.gov/pubmed/) data as the data collection began in 2016. A PubMed search was done for the years 1983, 1985, 1995, 2005, and 2015. Editorials, letters, and commentaries were excluded from the search, and the citations for the remaining entries were downloaded into EndNote X7 (Clarivate Analytics, Philadelphia, PA). Any entries that were published electronically in the desired year, but without an official publication date until the following year, were excluded. The collection was further reviewed to exclude all entries without authors, as well as those that were not original research (e.g. memorandums, meeting notes, and abstracts). The citation data was then exported into Microsoft Excel (Microsoft, Redmond, WA).

The full names of first and corresponding authors were collected, along with the country and state or providence (for those in the United States or Canada), position of the corresponding author within the author list (e.g. 1,2,3…last author), number of references cited, manuscript length (total page number), and number of times each manuscript had been cited were also

collected. The manuscript citation number was obtained from a Scopus search during the month of December 2016 to prevent variability if conducted at separate times.

Author gender for the first and corresponding authors was determined using the method of *Mimouni et. al*.[12] Briefly, "Baby Name Guesser" was used, which can be found at http://www.gpeters.com/names/baby-names.php. This program gives the most likely gender and a gender ratio by using the authors' first names. A ratio of 3.0 and above was considered to be correct. For any author having a ratio less than 3.0, an Internet search for the author's name was performed to assign a gender to complete the data. If such a search did not yield the author's gender, the entry was excluded for gender analyses (<0.1% excluded for both first and corresponding authors). Of note, there were only 13 manuscripts in which co-first authors were denoted and 21 manuscript in which co-corresponding authors were denoted. For these manuscripts all co-first and/or co-corresponding authors were identified as men or women and were included within our analyses.

Typically, the trainee or junior researcher may initially serve as first author, and then as they advance in their career move into the corresponding author position.[14] Therefore, we sought to determine whether women identified as first authors had at anytime by December 1, 2017 become corresponding authors (any publication). This was accomplished by completing a PubMed search in December 2017 for each of the female first authors and then manually examining each publication to determine whether they were listed as the corresponding author for any subsequent publications in which they were a co-author.

Countries were grouped into regions defined by the origin of the corresponding author. The United States and Canada were designated as North America. Mexico, along with Central America and South America, was designated as Latin America. Asia was defined as all Asian

countries east of Turkey, including the Middle East and Israel. The European continent including Russia and Turkey was designated as Europe. Although Turkey spans both Europe and Asia, we classified it as Europe, since it is a member of NATO and its most populous city, Istanbul (17 million), is on the European side.[15, 16] The other regions were Africa, and Australia/New Zealand.

Data for the gender and region of *JOR*® Editorial Board members (Editors, Associate Editors, and Editorial Board) for the same years was gathered, allowing us to compare gender and regional trends between the authors and the Editorial Board. Additionally, data for the gender of the ORS presidents over time was also collected.

Continuous data are reported as the mean ±1 standard deviation and discrete data are reported as frequencies and percentages. Analyses between groups of continuous data were performed using non-parametric tests due to the data not having normal distributions (Mann-Whitney U – 2 groups; Kruskal-Wallis test – 3 or more groups). Differences between groups of discrete data were analyzed by the Fisher's exact test (2 x 2 tables) and the Pearson's χ^2 test (greater than 2 x 2 tables). Trends over time for 2 x k tables were analyzed using the Cochran linear trend test. To assess the relationship between gender, time, and ORS presidents/first authors/corresponding authors a 3-way chi-square analysis or log-linear analysis for an AxBxC contingency table was completed.

For all statistical analyses a $p < 0.05$ was considered statistically significant. The majority of the statistical analyses were performed with Systat 10 software (Systat Software, Chicago, IL). The 3-way chi-square analyses were completed using the Vassar application (http://vassarstats.net/abc=application).

Results

From the five years analyzed (1983, 1985, 1995, 2005, 2015), a total of 638 articles met the inclusion criteria. There were 21 articles from 1983, 60 from 1985, 116 from 1995, 202 from 2005, and 239 from 2015.

Analysis by Region

North America, Europe, Asia, and Australia/New Zealand were the regions included for this analysis. Latin America and Africa were excluded due to the small number of manuscripts from these regions during the analyzed years. Over the 5 years analyzed, North America contributed 63.1% of total manuscripts, Europe 20.1%, Asia 13.3%, and Australia/New Zealand 3.1%. Analysis of North America was divided into countries and even further into states/provinces. The United States contributed 91% of manuscripts from North America and Canada the remaining 9%. Within the United States, manuscripts primarily came from California (19%), New York (13%), Massachusetts (9%), Pennsylvania (9%), and Ohio (7%). The 128 manuscripts from Europe were primarily from Germany (25%), United Kingdom (22%), and Switzerland (8%), with all other countries contributing 5% or less of the manuscripts. Of the 94 manuscripts from Asia, the majority were from Japan (45%). Other Asian countries with large contributions included China (21%) and Taiwan (16%). All other Asian countries contributed less than 5% towards the total published manuscripts. All of the manuscripts from Australia/New Zealand originated from Australia. Figure 1 provides a visual representation of the contribution of manuscripts from North America, Europe, and Asia.

Analysis over Time

The average number of authors increased from 3.7±1.9 in 1983 to 6.9±2.7 in 2015 ($p<10^{-6}$, Figure 2A). The average corresponding author position showed a similar trend, increasing from 1.5±0.7 in 1983 to 4.4±3.5 in 2015 ($p<10^{-6}$, Figure 2A). The number of collaborating institutions also increased from 1.6±0.9 in 1983 to 3.4±1.7 in 2015 ($p<10^{-6}$, Figure 2B). The average number of countries also increased between 1983 and 2015 (p=0.0008, Figure 2B). The average number of pages per manuscript showed an interesting and significant trend over time, decreasing from 8.8±2.8 in 1983 to 7.4±1.4 in 2005, but increased to 8.3±2.9 in 2015 (p=0.00004, Figure 2C). The average number of references per manuscript has increased significantly each year, from 26±14 in 1983 to 37±15 in 2015 ($p<10^{-6}$, Figure 2D). Of note, current author instructions limit manuscripts to 50 references. The number of citations normalized for the number of years since publication increased from 1.5±1.6 in 1983 to 3.8±3.6 in 2005, but decreased to 2.8±3.3 in 2015 ($p<10^{-6}$, Figure 2E).

Analysis by Gender over Time (Table 1)

For this analysis, 1983 had a small sample of only 19 manuscripts and all regions were combined. In 1983, 5% of first authors were women and there were no female corresponding authors. In 1985, female first authors remained at 5%, and 3% of manuscripts had female corresponding authors. In 1995 and 2005, women were first authors on 18% and 20% of manuscripts, respectively. Women as corresponding authors for 1995 and 2005 were 15% and 14%, respectively. Finally, 2015 saw a significant increase to 34% of first authors being women and 27% of corresponding authors being women (Cochran linear trend $p<10^{-6}$ and 0.000001 respectively).

Next, we examined whether female first authors became corresponding authors of subsequent publications identified within PubMed as of December 1, 2017. Over all years examined, 62% of female first authors had one or more corresponding author publications. We found no difference in the percentage of female first authors that became corresponding authors from 1983-2005 (76% average, range [74%-81%]). However, only 50% of 2015 female first authors had become corresponding authors by December 1, 2017.

Analysis by Gender across Regions

Over the entire time span, 23% of first authors were women and 15% of corresponding authors were women in North America. In Europe, these percentages were 28% and 27% respectively; in Asia, 13% and 13%; and in Australia/New Zealand 30% and 17%. These differences by region were borderline significant (p=0.046, Table 2).

Gender Changes across Regions over Time

Further analyses were performed to compare trends in author gender over time for the four major regions (Figure 3). In North America, there was a significant increase in the number of women as first authors over time (Cochran linear trend $p<10^{-6}$) (Figure 3A), going from 0% in 1983 to 40.5% in 2015. Europe also saw a trend toward an increase in female first authors, although it was not found to be significant (Cochran linear trend p=0.15, Figure 3A). Asia showed no trend over time, and Australia/New Zealand had a small sample size and did not show a significant trend over time. Regarding corresponding author, there was a significant increase in female corresponding authors over time in North America (Cochran linear trend p=0.0002, Figure 3B), going from 0% in 1983 to 23.6% in 2015. Europe also demonstrated an increase in

female corresponding authors over time (Cochran linear trend p=0.014, Figure 3B); going from 0% to 37.9% in 2015. Asia and Australia/New Zealand showed no significant trend for corresponding author gender.

Comparison of Editorial Board and Authors

For this analysis we excluded the year 1983 due to the small numbers of sub groups. From 1985 through 2015 the percentage of female first author, corresponding author, and Editorial Board members increased, with a concomitant decrease in male first author, corresponding author, and Editorial Board members (Figure 4A). Although there were a few statistical differences between certain categories, the overall trends for all three groups are extremely similar. There were also differences in the Editorial Board membership and origin of the manuscripts by region (Figure 4B).

Comparison of ORS Presidents and Authors

For this analysis, we also excluded the year 1983 due to the small numbers of sub groups. During the 65 year history of ORS, 6 women have been president. The first female president served in 1996. The other 5 female presidents served in 1999, 2010, 2013, 2014, and 2018. Figure 5 shows the percentage ORS presidents which were women (10 years proceeding the year in which manuscripts were analyzed), as well as the percentage of first and corresponding authors which were women, over time. As shown in Figure 5, the slope of the trend lines are fairly similar for the most recent 10 year interval, although the percentage of female ORS presidents initially lagged behind the percentage of female authors. Statistical analyses demonstrated a significant effect between all variables ($p<0.001$) (ORS president/first

author/corresponding author level, gender, and year). Between ORS president/first author/corresponding author level and gender there was a borderline effect ($p=0.042$). No significant effect was detected between ORS president/first author/corresponding author level and year ($p=0.12$). There was a significant increase in the number of female authors over time ($p<0.001$).

Discussion

The number of authors, corresponding author position, institutions, countries, and manuscripts has progressively increased since *JOR®'s* inaugural year in 1983. The number of authors has likely increased due to increased scientific complexity as well as the need for more collaboration amongst authors. Authorship has become a currency for academic success and career development, and as such, there has become more incentive for authorship involvement at the undergraduate, graduate, and professional levels.[14, 17-22] Multiple disciplines in the fields of science and medicine have come together to collaborate and provide their expertise to research projects due to an increased push for multidisciplinary healthcare.[23, 24] The significant increase observed in collaborations between different institutions and countries is likely due to advances in technology such as phone, email, and video conferencing, as geographical borders are no longer a major problem.

The number of publications has increased significantly over the years, which is likely due to growth and expansion of *JOR®*. Since the journal began in 1983, research in the United States and around the globe has seen increased funding and emphasis.[25-29] Researchers may be more productive, explaining the increase in publications between 1983 and 2015 in *JOR®*. Although all countries have increased output, the proportion of papers between the countries in the past 30

years has been vastly different. North America has produced almost triple the number of manuscripts compared to the other regions, and the United States accounts for 91% of the North American productivity. This may be expected as the *JOR*® is an American-based journal. Another possible explanation may be differences in regional economics. As an example, the United States has more institutions and spends more on research than any country in the world;[30] therefore, it may be expected that the United States would contribute a majority of research publications. Indeed, more research is being done in all fields and this holds true for medicine.[31] Further, for the United States, an Accreditation Council for Graduate Medical Education (ACGME) requirement of orthopaedic residency programs is that all residents must pursue scholarly activity, which can ultimately produce more publications.[32] Of note, the same requirement is held by the Royal College of Surgeons for Canadian orthopaedic surgery residents.[33] Within the United States, most of the papers were produced by institutions from the states California and New York. This is not unreasonable, as both of these states have the highest number of academic and research institutions within the United States, increasing their capacity for publication output.[34]

It is, however, interesting to note, that for some regions, the percentage of manuscripts contributed from each region is similar to the percentage of ORS members from that region (Figure 4C). For others, there are differences. For example, approximately 63% of all *JOR*® manuscripts originated from North America and approximately 73% of ORS members reside in North America (ORS member, country of residence data was based on data as of November 1, 2017, from the ORS Membership and Affiliate Relations Specialist). Similary, approximately 13% of *JOR*® manuscripts originated from Asia and 13% of ORS members reside in Asia. However, the percentage of manuscripts published from both Europe (20%) and Australia/New

Zealand (3%) was higher than the number of ORS members from those regions, 12% and 2%, respectively. For both Latin America and Africa, very few manuscript originated from these regions and ≤1% of ORS members indicated they were from those regions. The country of residence for 6% of ORS members was unknown. When excluding Africa and Latin America due to the small numbers, the differences between the ORS membership region of origin and region of origin for *JOR*® manuscripts were statistically significant ($p < 10^{-6}$). However, the trend remained that ORS member residence corresponds with where *JOR*® manuscripts originate. This seems logical, and may suggest that increasing ORS membership in focused regions may increase contribution of manuscripts from those regions.

In academia, publications are a metric for success and overall standing. Over time, publications in peer-reviewed, well-respected journals have an enormous impact on academic career development and advancement.[1, 14, 19-22, 35] Another objective of this bibliometric analysis was to investigate how the push for gender equality has resulted in changes in gender proportion by using data collected from *JOR®'s* published manuscripts from the past 30 year. It should be noted, that in this study gender was divided into two groups: men and women. While we acknowledge that some people do not associate themselves with either of these two genders (for example, transgender), with the public data/tools available, we could only subdivide the data into men and women. With this in mind, there was a progressive and striking increase in first and corresponding female authors (>5-fold increase for women as either first and/or corresponding authors) between 1983 and 2015.

If we examine the percentage point increase over time we see that for *JOR*®, there was a 29 point increase in female first authors (from 5%-34%) and a 27 point increase in female corresponding authors (from 0%-27%) from 1983-2015. *JOR*® has seen stronger improvements

than all bone/orthopaedic journals for which similar data have been recently published.[13, 36-39] Examination of data from the mid 1980s to 2015 from the *Journal of Bone and Mineral Research* shows a 12 point and 17 point increase in female first and corresponding authors,[13] *Bone* shows a 25 point and 14 point increase in female first and corresponding authors,[36] *Journal of Pediatric Orthopaedics* shows a 20 point and 12 point increase in female first and corresponding authors,[37] *Spine* shows a 0.9 and -0.3 point increase in women first and corresponding authors,[38] and *Journal of Hand Surgery* shows a 14 point increase in female first authors (corresponding author gender was not documented in that study).[39] That said the actual percentage of female first and corresponding authors for *JOR*® as of 2015 were 34% and 27%, respectively, which for first author is lower than that reported for both *Journal of Bone and Mineral Research* and *Bone* (48% each) and for corresponding author is lower than that reported for *Bone* (35%).[13, 36]

If we expand these comparisons across other fields of academic medicine, there is more diversity in the years studied and the types of comparisons made.[10, 12, 35, 40, 41] However, the overall trend was that the percentage of women serving as first and/or last author (not necessarily corresponding author as specifically identified for *JOR*®) increased over time.[10, 12, 35, 40, 41] Indeed, combined, the median percentage point increase for female first authors was 12.5 points [Range: -4 to 33], for female last authors was 10 points [Range: 5 to 27], or for female authors in an unspecified position was 6.5 points [Range: 1 to 10]. The median percentage of women serving as first authors in the most recent year tabulated was 36% [Range: 14 to 45], whereas the median percentage of women serving as last authors was 14% [Range: 7 to 38]. If both first and last author were studied for the same journal a lower percentage of women were last author as compared to first author.[10, 12] For all of the journals studied women made up less than 50% of the

authors.[10, 12, 35, 40, 41] Thus, the gender-based authorship trends appear to hold for *JOR*® as they do throughout academic medicine, but the actual values vary among journals/fields.

In general, the first author is usually the individual involved in the process from the beginning stages to direct involvement with manuscript preparation, while the corresponding author is generally the individual under whom the research is being conducted and may be considered an academic advisor.[17] Corresponding authors generally have the resources and knowledge to help design and oversee research projects, and are also responsible for communicating with others once the manuscript is published.[17] As detailed above, in many instances the first author may be a trainee or junior researcher, which with time and career advancement may transition into serving as the senior or corresponding author.[17] We found that on average 62% of *JOR*® female first authors transition into becoming corresponding authors. When the data was analyzed based on time since publication of their *JOR*® first author manuscript (i.e. >10 years), >76% of female first authors became corresponding authors on subsequent manuscripts. However, only 50% of female first authors on 2015 *JOR*® manuscripts were identified as corresponding authors on another manuscript, likely owing to stage of training and the short time since 2015. Importantly, these numbers (76% and 50%) if anything may be lower than actual percentages as from our methods we cannot determine whether name changes may have occurred, and all publications are not contained within PubMed. Also, as female first authors alone were assessed by this additional analysis, we do not know whether this percentage is in line with male counterparts or not. That said, it is logical that it takes time to advance from being a first author to a corresponding author, and that some people leave academic careers. Thus, we would not expect 100% of female (or male) first authors to become corresponding

authors, but would expect for that number to grow initially and then to level off with time, as was observed.

With regard to women from other regions, Asia had the smallest percentage of women as first and corresponding authors. While Asia has had an increase in female authors, it was not commensurate with the other regions. Cultural differences regarding the role of women in academics and professional fields may explain some of this lag observed in Asia.[42] Europe and North America showed a significant increase in female authors represented over time. This may be expected, as the number of women in the field is growing. Indeed, currently 40% of ORS associate members are women (in-training), 23% of ORS active members are women, and 18% of ORS former presidents were women. The percentages of in-training and active members mirrors the 34% female first authors and 27% female corresponding authors observed in 2015. Additionally, as shown in Figure 5, the percentage of female first and corresponding authors over time also mirrors the percentage of female ORS presidents over time. It is difficult to dissect a role model effect as that can easily take up to 5 years (or maybe even more). As an example, in the area of basic science, a female ORS president having an effect, might require a greater than 5 year impact (need to get a mentor, then financial support, do the research, then submit manuscript, and hopefully get published). With this in mind, the trend lines in Figure 5 are fairly parallel for the most recent 10 year intervals, although the percentage of female ORS presidents initially lagged behind the percentage of female authors. This is not surprising as to be the president of a Society, the candidate would have to have academic and leadership qualifications, such as key authorship roles on manuscripts in the field, before being elected. As the current ORS president is a woman and the 2nd vice president is a woman, and there are currently 7 of 16

board members that are women, it appears that ORS is making good progress in closing the gender gap by providing key female role models in its leadership.

However, as shown by our study as well as others, a gender gap remains between women and men for first and senior authorship.[10, 13] Although our study does not explicitly demonstrate cause and effect, several important trends have been identified which may provide *JOR*, ORS, and the orthopaedic field with strategies for further closing the gender gap. These are: 1. continue to increase participation of women in the field of orthopaedics (recruitment and retention); 2. continue to encourage senior females in the field to mentor/sponsor/coach female trainees; 3. continue to encourage senior males in the field to mentor/sponsor/coach female trainees; and 4. continue to encourage women to serve in leadership roles within the field including on editorial boards, advisory boards, and as president to serve as role models for the younger generations.

As evidenced by this study, considerable progress has been made over the past 30 years in closing the gender gap in academic medicine, specifically in a field dominated primarily by men, such as orthopaedic surgery. There has also been increased collaboration and globalization over time. Our study shows promise for increased equality, collaboration, and productivity in orthopaedics and academic medicine for decades to come.

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References

1. Schwab K, Samans R, Zahidi S, et al. 2016. The Global Gender Gap Report 2016: World Economic Forum; p. 391.
2. Lautenberger DM, Dandar VM, Raezer CL. The state of women in academic medicine: the pipeline and pathways to leadership, 2013-2014: Association of American Medical Colleges. Available from: https://members.aamc.org/eweb/upload/The%20State%20of%20Women%20in%20Academic%20Medicine%202013-2014%20FINAL.pdf
3. González-Alcaide G, Park J, Huamaní C, et al. 2015. Evolution of Cooperation Patterns in Psoriasis Research: Co-Authorship Network Analysis of Papers in Medline (1942–2013). PloS One. 10:e0144837.
4. Pintér A. 2015. Changing authorship patterns and publishing habits in the European Journal of Pediatric Surgery: a 10-year analysis. Eur J Pediatr Surg. 25:353-358.
5. Tilak G, Prasad V, Jena AB. 2015. Authorship inflation in medical publications. Inquiry. 52:0046958015598311.
6. Baek S, Yoon DY, Cho YK, et al. 2015. Trend toward an increase in authorship for leading radiology journals. Am J Roentgenol. 205:924-928.
7. Piper CL, Scheel JR, Lee CI, Forman HP. 2016. Gender trends in radiology authorship: a 35-year analysis. AJR Am J Roentgenol. 206:3-7.
8. Hettrich CM, Hammoud S, LaMont LE, et al. 2015. Sex-specific analysis of data in high-impact orthopaedic journals: how are we doing? Clin Orthop Relat Res. 473:3700-3704.
9. Lehman JD, Schairer WW, Gu A, et al. 2017. Authorship Trends in 30 Years of the Journal of Arthroplasty. J Arthroplasty. 32:1684-1687.
10. Jagsi R, Guancial EA, Worobey CC, et al. 2006. The "gender gap" in authorship of academic medical literature—a 35-year perspective. New Engl J Med. 355:281-287.
11. Reich M, Shaw J, Barrett I, et al. 2014. Level of evidence trends in the Journal of Bone and Joint Surgery, 1980-2010. Iowa Orthop J. 34:197.
12. Mimouni M, Zayit-Soudry S, Segal O, et al. 2016. Trends in Authorship of Articles in Major Ophthalmology Journals by Gender, 2002–2014. Ophthalmology. 123:1824-1828.

13. Wininger AE, Fischer JP, Likine EF, et al. 2017. Bibliometric Analysis of Female Authorship Trends and Collaboration Dynamics over JBMR(R)'s 30-Year History. J Bone Miner Res. 32:2405-2414.
14. Halperin E. 1999. Publish or perish-and bankrupt the medical library while we're at it. Acad Med. 74:470-472.
15. World Population Review. Population of Cities in Turkey (2017). 2017. Available from: http://worldpopulationreview.com/countries/turkey-population/cities/
16. North Atlanta Treat Organization (NATO). What is NATO? Available from: https://www.nato.int/nato-welcome/
17. Bhattacharya S. 2010. Authorship issue explained. Indian J Plast Surg. 43:233.
18. Angell M. 1986. Publish or perish: a proposal. Ann Intern Med. 104:261-262.
19. Neill US. 2008. Publish or perish, but at what cost? J Clin Invest. 118:2368.
20. Brumback RA. 2012. "3.. 2.. 1.. Impact [Factor]: Target [Academic Career] Destroyed!" Just Another Statistical Casualty. J Child Neurol. 27:1565-1576.
21. Erren TC, Shaw DM, Morfeld P. 2016. Analyzing the publish-or-perish paradigm with game theory: The prisoner's dilemma and a possible escape. Sci Eng Ethics. 22:1431-1446.
22. Hasan SS, Ahmadi K. 2017. Publish or perish: a mandate with negative collateral consequences. Acad Med. 92:140.
23. Subramanyam K. 1983. Bibliometric studies of research collaboration: A review. Inf Sci. 6:33-38.
24. Aboukhalil R. 2014. The rising trend in authorship. The Winnower. 2:e141832.
25. Payne AA, Siow A. 2003. Does federal research funding increase university research output? Advances in Economic Analysis & Policy 3.
26. Hendrix D. 2008. An analysis of bibliometric indicators, National Institutes of Health funding, and faculty size at Association of American Medical Colleges medical schools, 1997–2007. Journal of the Medical Library Association: J Med Libr Assoc. 96:324.
27. Jacob BA, Lefgren L. 2011. The impact of research grant funding on scientific productivity. J Public Econ. 95:1168-1177.
28. Auranen O, Nieminen M. 2010. University research funding and publication performance—An international comparison. Res Policy. 39:822-834.

29. Wang X, Liu D, Ding K, Wang X. 2012. Science funding and research output: a study on 10 countries. Scientometrics. 91:591-599.
30. Jaffe AB. 1996. Trends and patterns in research and development expenditures in the United States. Proc Natl Acad Sci U S A. 93:12658-12663.
31. Larsen PO, Von Ins M. 2010. The rate of growth in scientific publication and the decline in coverage provided by Science Citation Index. Scientometrics. 84:575-603.
32. Carek PJ, Dickerson LM, Diaz VA, Steyer TE. 2011. Addressing the scholarly activity requirements for residents: one program's solution. J Grad Med Educ. 3:379-382.
33. Royal College of Physicans and Surgeons of Canada(RACS). Specialty Training Requirements in Orthopedic Surgery. 2015. Available from: http://www.royalcollege.ca/cs/groups/public/documents/document/mdaw/mdg4/~edisp/088801~1.pdf.
34. National Center for Education Statistics USDoE. Colleges & Universities in the United States of America and U.S. Territories. Available from: https://nces.ed.gov/programs/stateprofiles/.
35. Filardo G, da Graca B, Sass DM, et al. 2016. Trends and comparison of female first authorship in high impact medical journals: observational study (1994-2014). BMJ. 352:i847.
36. Khan F, Sandelski MM, Rytlewski JD, et al. 2018. Bibliometric analysis of authorship trends and collaboration dynamics over the past three decades of BONE's publication history. Bone. 107:27-35.
37. Fischer JP WA, Scofield DC, Tucker A, Kacena-Merrell EJ, Whipple EC, Kacena MA, Loder RT. Historical analysis of bibliometric trends in the Journal of Pediatric Orthopaedics with a particular focus on gender. J Pediatr Orthop. 38:e168-e171
38. Brinker AR, Liao JL, Kraus KR, et al. 2018. Bibliometric Analysis of Gender Authorship Trends and Collaboration Dynamics over 30 Years of Spine 1985 to 2015. Spine. [Epub ahead of print].
39. Gu A, Almeida N, Cohen JS, et al. 2017. Progression of Authorship of Scientific Articles in The Journal of Hand Surgery, 1985–2015. J Hand Surg Am. 42:291. e291-291. e296.
40. Dickersin K, Fredman L, Flegal KM, et al. 1998. Is there a sex bias in choosing editors?: Epidemiology journals as an example. JAMA. 280:260-264.

41. Bhattacharyya N, Shapiro NL. 2000. Increased female authorship in otolaryngology over the past three decades. The Laryngoscope. 110:358-361.
42. Aiston SJ, Jung J. 2015. Women academics and research productivity: an international comparison. Gend Educ. 27:205-220.

Figure Legends

Figure 1: Maps showing the countries and states/provinces from which publications are originating. Map of A) North America; B) Europe; and C) Asia showing the countries or states/provinces contributing published manuscripts. Black represents the highest percentage of manuscripts published in the country or state/province. White indicates no manuscripts were published in the country or state/province.

Figure 2: Trends over time period analyzed. A) Average number of authors and average corresponding author position per article. B) Average total number of institutions and total number of countries collaborating per article. C) Average number of printed pages per article. D) Average number of references per article. E) Average number of citations per article normalized to the number of years each article was available for access. Data are presented as the mean ± 1 standard deviation of the mean.

Figure 3: A) Changes in first authorship gender over time and by region. B) Changes in Corresponding authorship gender over time and by region. Of note, 1983 was excluded from these figures to simplify the image.

Figure 4: A) Changes in gender composition over time for first and corresponding authors and Editorial Board members. FA denotes first author, CA denotes corresponding author, EDT denotes Editorial Board, W denotes women, and M denotes men. B) Region of origin for *JOR*® manuscripts and its Editorial Board members. These differences were statistically significant

($p<10^{-6}$). C) Region of origin for *JOR*® manuscripts and the Orthopaedic Research Society membership. These differences were statistically significant ($p<10^{-6}$).

Figure 5: Percentage of women serving as ORS president, first author, or corresponding author over time. FA denotes first author, CA denotes corresponding author, PRES denotes ORS President.

Table I: Percentage of female and male first and corresponding authors between 1983 and 2015

	% Female 1st Authors	% Male 1st Authors	% Female Corresponding Authors	% Male Corresponding Authors
1983	5	95	0	100
1985	5	95	3	97
1995	18	72	15	85
2005	20	80	14	86
2015	34	66	27	73

Table II: Percentage of female and male first and corresponding authors across regions

	% Female 1st Authors	% Male 1st Authors	% Female Corresponding Authors	% Male Corresponding Authors
North America	23	77	15	85
Europe	28	72	27	73
Asia	13	87	13	87
Australia/NZ	30	70	17	83

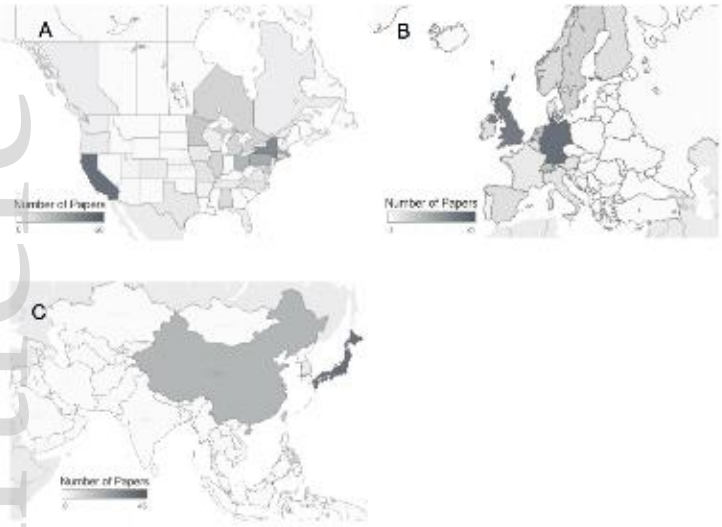

Figure 1

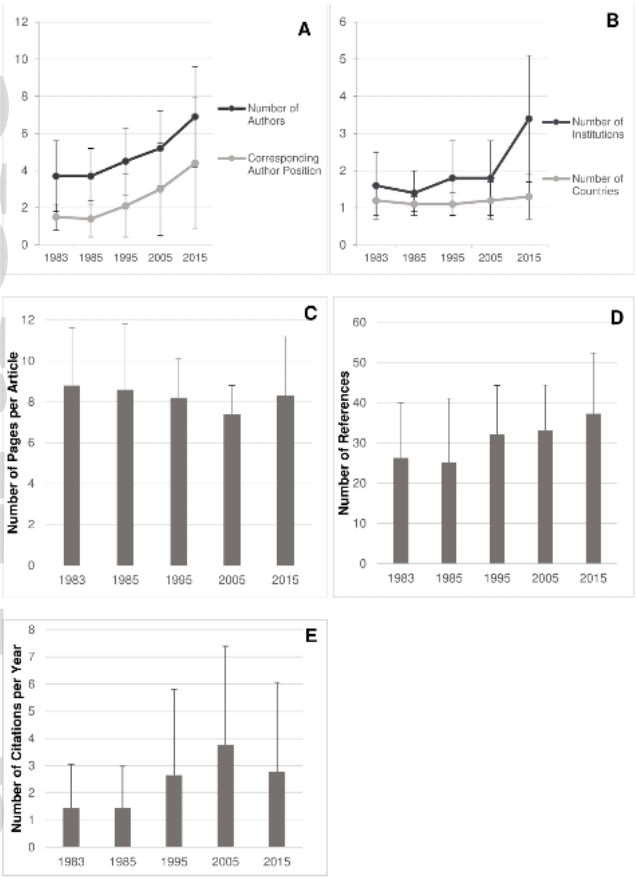

Figure 2

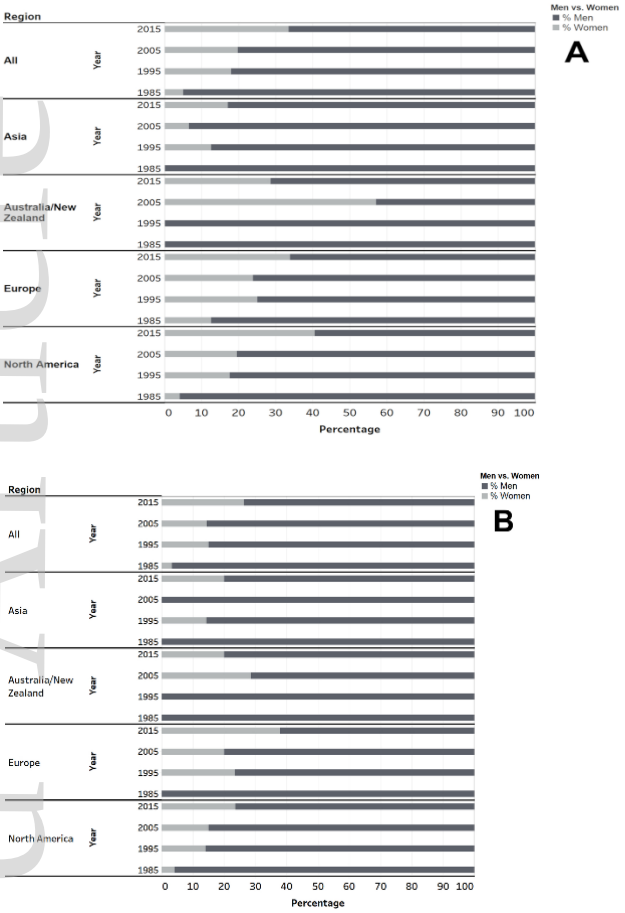

Figure 3

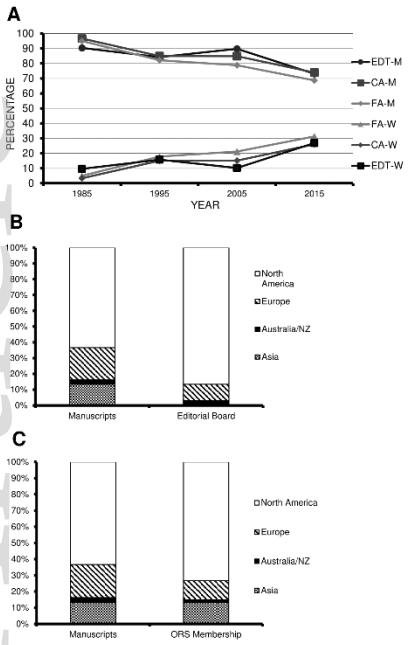

Figure 4

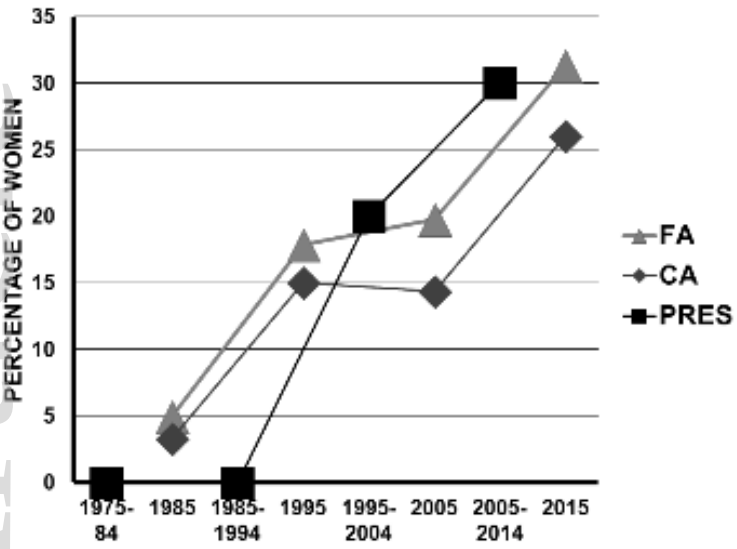

Figure 5